Honors Project Report

Green Roofs as a Solution to Stormwater Management Issues: A Problem with October Planting Date in Columbus, OH

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Abstract

As a result of widespread urban development and replacing natural vegetative surface with non-pervious pavement, the Earth's natural water cycle is disrupted and water can no longer permeate back into the ground. This disruption forces stormwater over parking lots and city streets, into storm drains and eventually into rivers and streams. If the stormwater system is combined with wastewater lines, then a rain event will likely lead to even greater levels of dangerous contaminants to the health of people and the environment. Not only is contamination of the water an issue, but also the overwhelming quantity of water that flows into creeks during a rainstorm leads to flash flooding and bank erosion.

This research examines green roofs—vegetative surfaces on the roof of buildings—in urban environments, specifically the campus of The Ohio State University, as a solution to the overburden and pollution of stormwater runoff. Through literature review, data collection, case study and industry interviews, this honors project report discusses green roofs as a stormwater management strategy with consideration of growing climate in Columbus, OH.

Introduction

Although the Earth's surface is comprised of 70% water, only 2.5% is fresh water and most of that is locked up in frozen mass, leaving less than 1% of all that water in our rivers and streams accessible to humans. With a population of 7 billion and growing, it is critical to protect these rivers and streams from contaminants.

Water moves in a natural cycle through the earth and its atmosphere. It evaporates or transpires into the atmosphere where it condenses and becomes heavy enough to fall back to the earth's surface in the form of precipitation. If unobstructed, rainwater will hit the ground and percolate back into the ground water, renewing the natural water cycle until it evaporates again back into the air.

Growth of The Ohio State University in the last 100 years has created a mini-metropolis in the City of Columbus - a thriving expansion of buildings, sidewalks, streets, athletic arenas and medical centers to accommodate more than 100,000 people. So while development is essential for success, we have paved over the original natural landscape and replaced it with hardscape. According to a study on rainfall catchment calculations, one inch of rain water hitting one acre of asphalt means 27,000 gallons of water (Lancaster, 2006). When rain cannot penetrate the ground because it is paved, it follows the path of least resistance to the nearest drain and ultimately into a river or creek.

Along its path, water travels over rooftops, streets and parking lots collecting oil, paint, debris, and lawn care chemicals. Depending on the sewer configuration, this polluted water then either flows untreated directly into the river, or is combine underground with a wastewater system (human and industrial waste) and sent to our wastewater treatment facilities.

However, during heavy rain events, these combined sewer systems often exceed capacity and in order to prevent basement or street backups, combined sewer overflow (CSO) outlets send waste and stormwater combined to overflow directly into the Olentangy River without any treatment. This is unhealthy as pollution affects the water quality and the human and wildlife that come into contact with it.

Proof and Significance of Problem

To understand why excess stormwater runoff is a problem, we discuss the impact of combined sewer overflows, CSOs. In an early 2001 address to Congress on the implementation of CSO control policy, the Ohio EPA warned that untreated water contributes to common diseases such as hepatitis, gastric disorders, dysentery, and swimmer's ear. Additionally, the EPA warns to avoid contact with the water (boating, swimming and fishing) near a CSO discharge location, particularly after a rain event. These discharges are destructive to fish populations, public recreational value, and contaminate drinking water, which threatens public health (USEPA, 1999).

Combined sewer overflow frequency depends on several variables, including the size of area draining into the sewer, the size of the sewer itself, rain events, etc. Therefore, some combined outlets may discharge every time it storms, while some discharge only a few times a year. This makes quantifying frequency and impact of CSOs difficult, since each one creates a unique situation.

There are three (3) CSOs in the immediate university area that are received by the Olentangy River: a) corner of Frambes Ave & Tuttle Park, b) Biology Annex (1791 Neil Ave) at OSU, and c) Perry St & King Ave. **(Figure 1.1)**. Of the total 42 overflow cases in 2011, 31 were at Lane Avenue, just .6 miles from the site of the proposed Green Roof at Howlett Hall. **(See Case Study)**

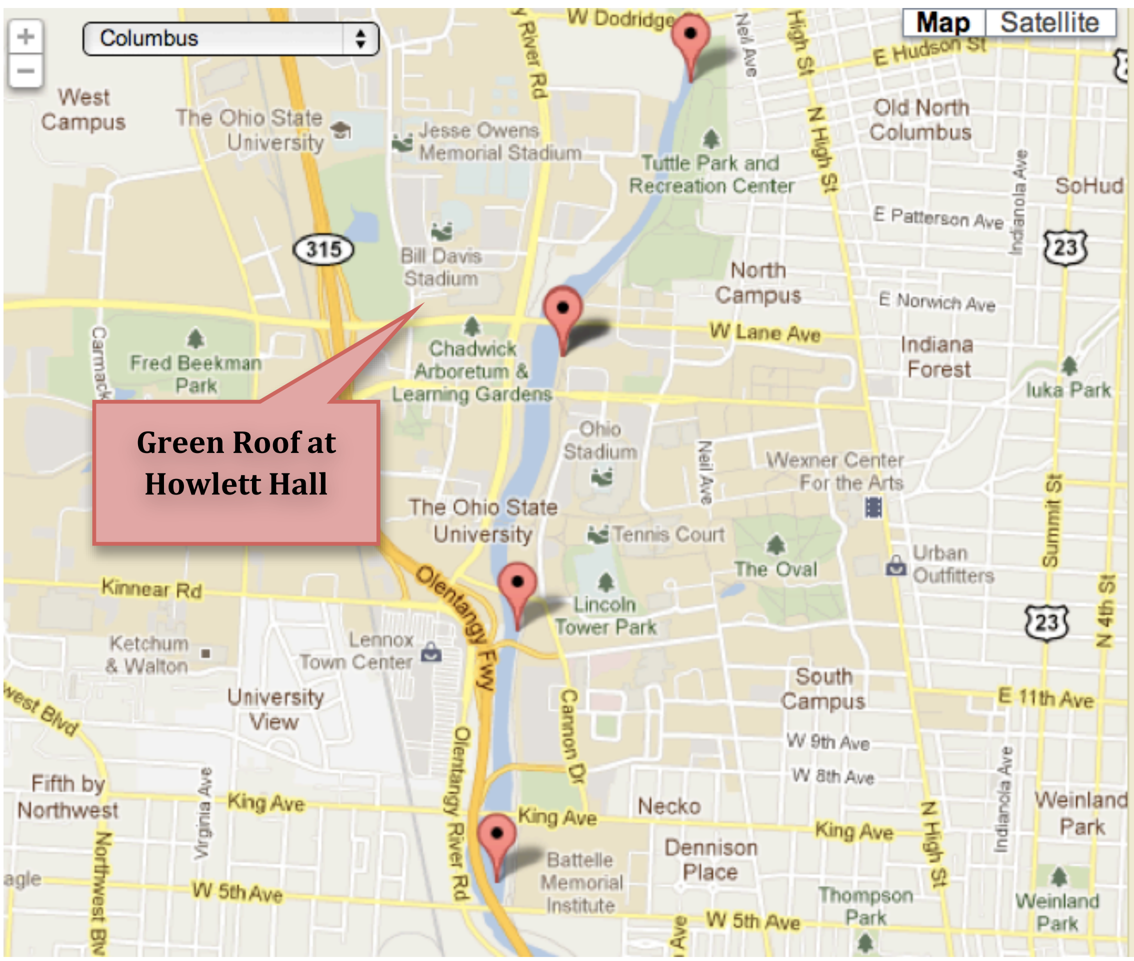


Figure 1.1 Combined sewer overflow (CSO) outlets received by the Olentangy River near The Ohio State University. Photo Source: Google Maps

The Ohio EPA no longer allows the construction of Combined Sewers, so all new sewer lines must separate water - sending wastewater to the treatment plant and stormwater to replenish surface waters.

Moving Forward

As cites are required to comply with the Clean Waters Act, municipalities must take action to reduce their volume of contaminated water discharged into the receiving waters. There are two approaches to obtaining this goal:

a. Repair and expand the underground combined sewer outlets (CSOs) to handle more stormwater
b. Integrate Low-Impact Development (LID) at grade - like bioretention, green roofs, rain gardens, etc. - to mitigate stormwater and slow its impact on the combined sewer outlets

The first approach is historically more common. In 2010, the City of Columbus Department of Public Utilities started the first phase of a $350 million rehabilitation project digging a 20ft diameter relief tunnel over 4.5 miles long in downtown Columbus. The tunnel is designed to be an environmental solution by diverting water from the existing overflow lines, however this scope of construction 170ft below ground creates a different kind of environmental hazard.

The second approach of green infrastructure seems to be gaining in popularity. The City of Philadelphia Division of Water has developed a 20-year plan called “Green City, Clean Waters” to manage and use rainwater through green infrastructure. Green infrastructure, or low-impact development such as green roofs, rain gardens, and trees help reduce the impacts of stormwater runoff on combined sewers by reducing, slowing, and filtering it. EPA Administrator Lisa P. Jackson explains, “Instead of investing in one project that treats one concern, green infrastructure allows us to protect the health of our waters, save money and make our communities more attractive places to buy homes and build businesses.” Funding for both programs will come partially from an increase in water utility bills, but only one of them will result in recreational parks and green space. Philadelphia and other cities including Toronto, New York City, and Chicago also offer financial incentives and tax credits for green infrastructure.

The Solution – Green Roofs

If replacing vegetated surfaces with pavement is the main problem for the health of our water supply, then it seems restoring our urban environments with vegetated surfaces is the solution. This paper discusses green roofs as a specific form of low-impact development to serve as the solution to stormwater crisis.

Green roofs, sometimes called eco roofs, are vegetated areas above a structure either at, above or below grade, (Bruce and Snodgrass 14) Ecological benefits of green roofs include increased green space, added insulation for less energy use, increased biodiversity, and reduction and purification of storm water runoff. As plant material on the roof absorbs and uses rainfall through a process called transpiration, they are cleaning and cooling the surrounding air. Plant transpiration is critical for green roof results and contributes to roughly 50-90% of the storm water runoff. (Bruce and Snodgrass, 2008).

Previous studies at the renowned green roof research facility at Michigan State look at the plant success rates of various species at varying soil depths and planting season. In a three-year trial at Michigan State University, nine sedum species were tested in substrate depths approximately 1, 2 and 3 inches. The success rate of the plants planted in spring were compared to a duplicate planting in and then evaluated the following June. Overall, spring planting exhibited far greater survival rates (81%) compared to autumn (23%) across all substrate depths. Three species (Sedum cauticola 'Lidakense', S. floriferum, and S. sexangulare) were not affected by season of planting. Sedum cauticola barely survived in any of the tests, but the latter two showed nearly 100% survival for both planting seasons. (Getter and Rowe, 2007).

Problem Identification and Justification

Case Study

In consideration of the impact of green roofs on stormwater mitigation, a retrofit green roof at Howlett Hall was selected as a case study for review. Chadwick Arboretum plans to install a 13,000 s.f. green roof at 2001 Fyffe Ct., Columbus, OH 43210. Columbus averages 37 inches of rainfall per year (Ohio Department Natural Resources). At that rate, calculations show that Chadwick Arboretum Green Roof at Howlett Hall, located on Ohio State's main campus and within one mile of the Olentangy River, will retain 1.35 inches of rainwater and a total storage of 8,409 gallons. This will reduce the impact to the watershed system by more than 250,000 gallons of water each year. (Hydrotech Hydrology Tool, 2011) By reducing flow, there is the potential to reduce Combined Sewer Overflow.

In an effort to synchronize with Ohio State's roof replacement schedule, which is due for completion in October 2012, the growing medium and vegetation will need to be installed immediately upon completion to protect the new waterproofing membrane. Given the chance that construction will not finish on time, it would be likely that the plants will not be installed until November 2012. There is concern about the success of the plant establishment if planted this late in the season.

Previous research addressed success of sedum species in varying substrate depths and planting season, but did not specifically address how these characteristics perform in Columbus, Ohio. This research will provide deeper insight into the recommended plants to use for green roof applications in the microclimate at The Ohio State University by showing the success rate of various sedum species at differing substrate depths and planting dates. The results will provide significant basis for future green roofs in this region, minimizing duplicated trial and error.

Objectives

The specific objectives of this research are to:

1. Conduct a performance evaluation of specific sedum species grown in various substrate depths and planted in the fall (October/November) in Columbus, Ohio.
2. Provide visibility for green roofs
3. Provide data specific to regional climate to serve as a streamlining tool for future projects.

Methods and Materials

A 2-month predictive correlational study of two substrate blends was conducted to evaluate the establishment success rate of (3) sedum and (1) succulent species when planted in 4- in., 5-in., and 6-in. depths of media during late Fall.

The three characteristics are:

1. Substrate composition and depth
2. Plant species and size
3. Planting date

1. Substrate Composition and Depth

Green roof substrate, or growing medium, is an engineered combination of organic and inorganic matter that serves to anchor the plants, drain water from the roof and sustain the healthy growth of plant life (Bruce 40). Organic components including compost or peat contribute to the soil structure and vary in percentage based on the desired plant type. Inorganic or mineral matter such as sand, gravel and expanded aggregate provide nutrients and porosity for air and water to move through the system.

In early October 2011, green roof testing platforms were designed and partitioned to compare two of the leading substrate blends in the industry, Hydrotech and Sarnafil (Figure 1.2). The Hydrotech mix was extracted locally, blended by Kurtz Bros. in Alexandria, Ohio, and transported loose by truck to Howlett Hall. For volume blending, the substrate contains more than 50% Haydite, (expanded shale), less than 30% Envirospec sand and less than 30% yard waste compost. Sarnafil substrate was manufactured and shipped in bags from Chicago, IL. This extensive blend contains 5-10% organic matter.

Hydtrotech **Sarnafil**

Figure 1.2 Substrate side-by-side comparison of freshly laid substrate.

Thomas Hileman, Megan Welsh and Dan Dello-Stritto constructed three testing platforms (Figure 1.3) using the following materials:

a. (9) 2x8-12ft pressure treated pine lumber

b. Agricultural mesh

c. 1” gravel

d. landscape filter fabric

e. 1 cu. yd. Saranfil substrate

f. 1 cu. yd. Hydrotech substrate

Oriented strand board, OSB covered a thin sheet of clear plastic was used for the base of the frames with two 1-in holes drilled in each partitioned box for draining. 1-inch aggregate drainage layer covered the plastic, then a landscape filter fabric and finally measured depths of substrate at 4-in, 5-in and 6-in.

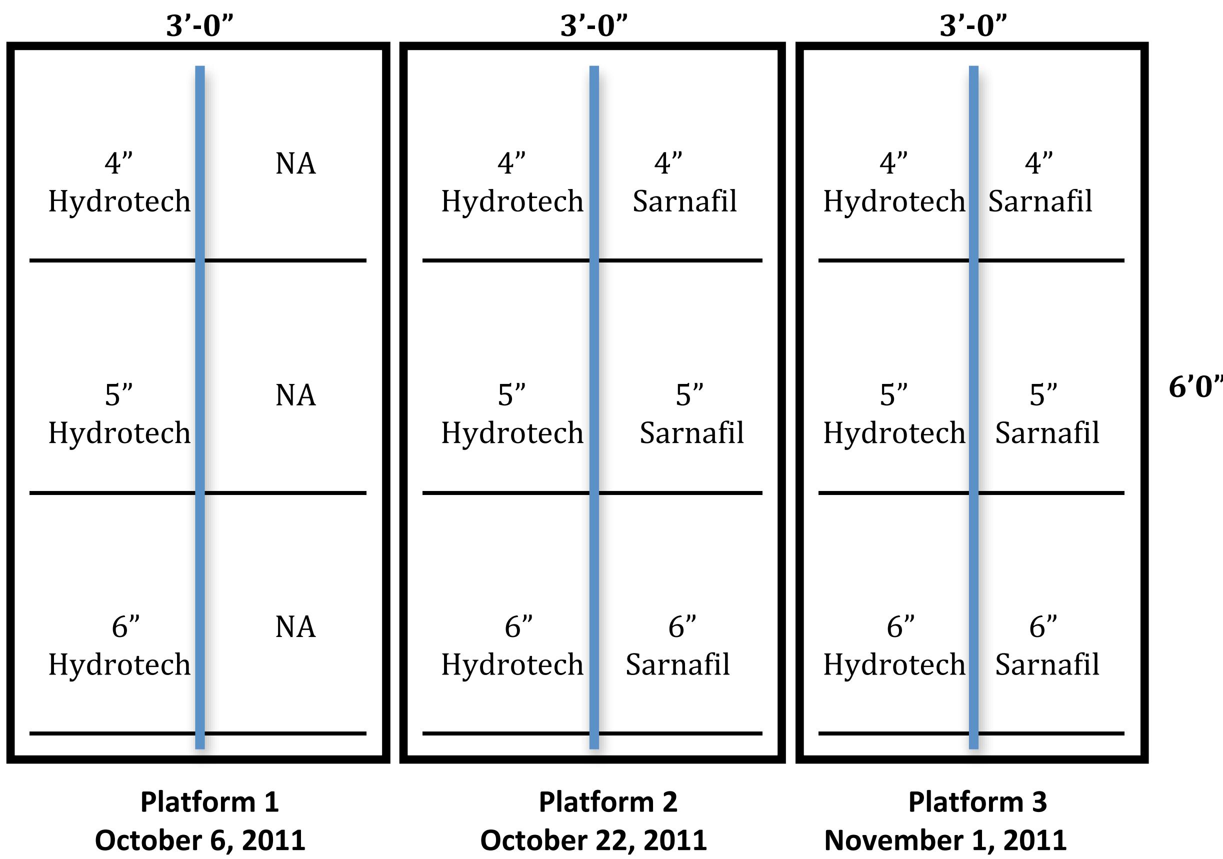


Figure 1.3 A sketch-up plan of the partitioned planting dates and substrate depths. Each platform is 3’-0” x 6’-0” and divided into three levels of substrate depths; 4, 5, and 6inches.

2. Planting Date and Conditions

Throughout October 2011, screening of plant species was conducted on Howlett Hall’s south-facing lower roof. Due to the high levels of precipitation, there was no manual irrigation.

Platform 1: Thursday, October 6, 2011

Sarnafil growing media had not been delivered at this point, so the first planting was in

Hydrotech media only. The temperature was unusually warm High 77˚ and Low 47˚, and two days later the ambient temperature in Columbus reached 81˚F, 16 ˚F above normal. Average monthly precipitation was 3.68 inches, approx. 1 inch above normal.

Platform 2: Saturday October 22, 2011

High 58˚, Low 34˚

Platform 3: Thursday November 1, 2011

High 59˚F, Low 35˚F Mean monthly temperature was 4.3˚F above normal

Average 4.77 inches of rain, 23% of which happened in one 24-hr event on November 14, 2011.

3. Plant Species and Size

The following plugs and quart-size perennials were donated by Millcreek Gardens, in Ostrander Ohio.

A. Sedum Kamtschaticum. Stonecrop (Zone 4) Yellow flowers bloom late season, dark green foliage with slight orange in the fall. This 4-9" tall plant will spread readily and prefers full sun.

source: MillCreek Gardens

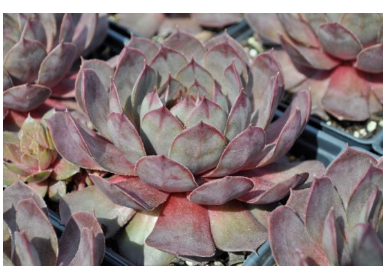
B. Sedum refelxum ‘Angelina’. Stonecrop (Zone 3) Bright yellow foliage, low growing and does well in containers. Some have had trouble overwintering them successfully. Full sun Grows 3-6", spread 18".


source: MillCreek Gardens

C. Sedum spurium ‘Fuldaglut’. Stonecrop (Zone 4) This cultivar displays red foliage and grows to 4" in full sun and average to poor soil types.


source: MillCreek Gardens

D. Sempervivum ‘Silverine’. Hens and Chicks (Zone 3) These succulents are evergreen for a four-season appeal and produces flowers in summer that reach 8-12". Require a full sun and excellent drainage. The plants are stoloniferous and develop new offsets at the base of the mother plant.


source: MillCreek Gardens

Results and Discussions

In order to determine how these plants perform through the winter, complete results of this research will be available in April 2012 on http://thechadwickgreenroofproject.weebly.com. At the time of this report, plants across all three platforms and depths show successful establishment, and it is hypothesized that they will overwinter. The three characteristics – a) substrate composition and depth, b) plant species and size, and c) planting date - do not appear to affect one another at this point, nor the likeliness of success in overwintering.

After 62 days, the performance of the Sedum reflexum 'Angelina' in Platform 1 showed increase in spread by .75 inches and new rosettes have spread from the Hens and Chicks. After 42 days, the performance of Platform 2 also shows steady increase in size and spread. Further monitoring of cover percentage will continue to be monitored in coverage and health. An updated analysis will follow.

Limitations

Non-typical factors contributing to the research include:

1. A steam vent near the testing site blows warm, moist air on the green roof platforms. This affects the temperature and humidity of the testing environment.
2. All plants were propegated at the same time but planted in phases, so the plants that went on the roof later in October and November spent more time in the greenhouse.

Further Research

The growth progress and percent coverage of the plants in each platform box will be monitored in February 2012 and again in April 2012. The condition of the plants will be analyzed based on the correlating outdoor temperature patterns recorded by temperature data loggers nearby on the Howlett Hall roof. In an effort to avoid skewing of temperature readings from the steam vent, the data logger is positioned outside of its reach, approximately 75 ft from the testing plots.

Future research will measure the plant leaf area with the use of a software tool such as SigmaPlot or SigmaPlan. Recorded weekly temperatures will show average temperature patterns as well as extreme highs and lows, which will help categorize issues found with the success of the plants that are not related to original planting date.

The research findings will be able to determine whether green roof plants can successfully be installed in October in Columbus, OH.

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